

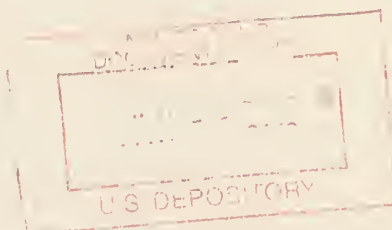
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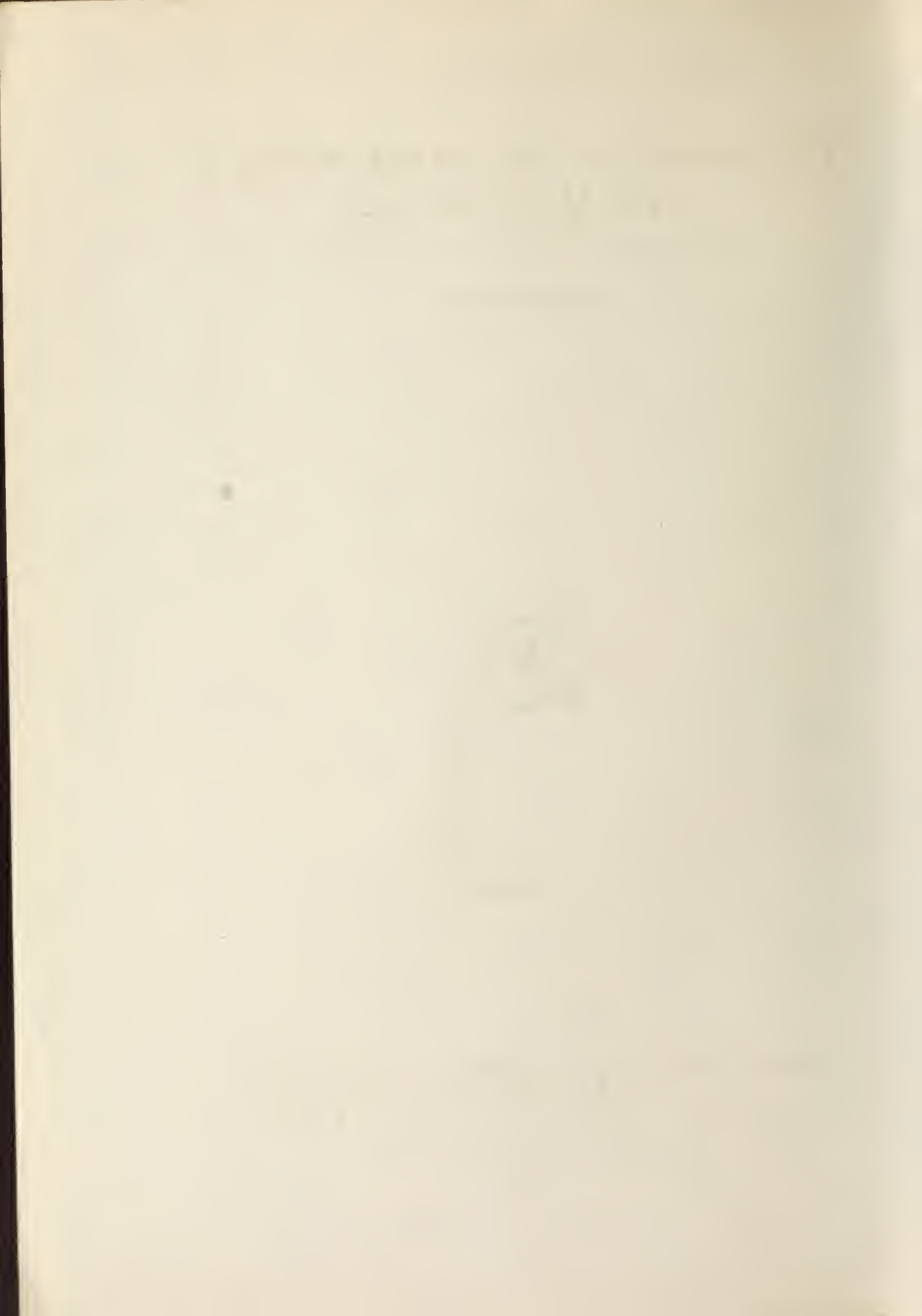
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KILN SCHEDULE FOR BLACK WALNUT GUNSTOCK BLANKS

By

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The rapid mobilization of a large army has greatly increased the demand for dry black walnut gunstock blanks. Holdover supplies of dried blanks are depleted and most gunstocks are now manufactured from material direct from the kiln, thus further taxing the already overloaded kiln capacity of the lumber-producing and wood-using industries.

During World War I, black walnut gunstock blanks green from the saw were dried successfully in the water-spray type of kiln according to methods worked out at the Forest Products Laboratory, and with varying degrees of success in natural-circulation kilns. Since then the natural-circulation kiln has been used rather extensively for drying both green and air-dried gunstock material. Drying in such kilns, however, requires considerable time, often more than 3 months for fully green stock.

Meanwhile, the efficiency of the lumber dry kiln has been improved by the application of mechanical refinements and better design.

The modern type of dry kiln with forced circulation and automatic control of temperature and relative humidity has made possible considerable reduction in the drying time of gunstock blanks. To determine what further reduction in drying time might be obtained by the use of accelerated kiln schedules, and to study the feasibility of such accelerated schedules, the Forest Products Laboratory during the past year or more has undertaken a series of experimental kiln runs designed to study several factors of drying. Among these are (1) the effect and desirability of preliminary steaming; (2) the efficiency of various end coatings in retarding end drying and thus in reducing end checking and end honeycombing; and (3) drying conditions, including initial conditions of temperature and relative humidity conducive to rapid drying without degrade, intermediate changes of temperature and relative humidity, final temperatures and relative humidities, and final conditioning treatment for relief of drying stresses.

The results of these drying experiments indicate that faster drying is possible than has been customary in the past and that certain definite limits of drying conditions exist beyond which drying cannot be accomplished without prohibitive degrade.

Preliminary Steaming

In the manufacture of black walnut gunstocks, green flitches or blanks should not be steamed before kiln drying. The steaming of green black walnut lumber to darken the sapwood is standard practice in industry, and users of black walnut lumber prefer the steamed stock. Steaming of 4/4 stock does darken the sapwood materially, making a more uniform color throughout the piece. The color change is greatest at or near the surface, however, and gunstocks that are carved from thick blanks either steamed or unsteamed require the application of stain to the sapwood during the finishing operation to obtain a sufficiently uniform color.

Results of experiments indicate that preliminary steaming does not reduce the final kiln drying time.

Tests of matched steamed and unsteamed material indicated that steaming for 3 days at 160°, 180°, and 200° F. under saturated conditions produced a significant decrease in toughness. The decrease ranged from about 6 percent for steaming at 160° F. to 13 percent in the wood steamed at 200° F., indicating that toughness decreases with increases in the preliminary steaming temperature.

Preliminary steaming of green blanks also contributes to the development of end and surface checks that are often sufficiently severe to warrant rejection.

Effective End Coating Required

The need of a suitable end coating to retard end drying and resultant end checking, especially for a refractory species such as black walnut, has long been recognized. Considerable attention was given to this problem when black walnut gunstock blanks were dried during World War I. The end coatings of rosin and lampblack and mixtures of rosin and coal-tar pitch used at that time were effective within the temperature limits used then, but, when higher temperatures were considered, additional experimental work on end coating was necessary to determine the ability of various coatings to adhere readily, to withstand handling, and to maintain an effective moisture barrier during drying. The results of such experiments indicate that hot coatings are more desirable for green blanks than are coatings applied cold. Hot coatings can be applied successfully by holding the end of the green blank against a power-driven roller partly submerged in a vat of molten end-coating material. The roller of this equipment should revolve at approximately 40 revolutions per minute, and the temperature of the coating when applied should be between 360° and 420° F., depending upon the particular coating used. Various coal-tar pitches, rosins, and asphalts were tried, separately and in different combinations.

An end-coating mixture was developed that has proved effective and has been used commercially. The material consists of:

60 parts 213° F. coal-tar pitch
25 parts 155° F. coal-tar pitch
15 parts 210°-220° F. asphalt

Mixtures of either rosin or high-melting-point asphalts and high-melting-point coal-tar pitches are also satisfactory, and some asphaltic enamels have shown promise. The addition of rosin has been advocated by some operators to increase the adhesiveness of pitch coatings. Ordinary roofing pitches and asphalts and 155° F. coal-tar pitch, used alone, are not satisfactory.

An adequate end coating is necessary because of its ability to protect stock against degrade due to end checking. There is an upper temperature limit for every coating beyond which complete protection will not be afforded.

Drying Conditions

The initial conditions of temperature and relative humidity are generally limited to those ranges which do not cause surface checking. Black walnut is not particularly susceptible to surface checking; thus the initial conditions are limited by the danger of end checking, which in turn is controlled by the effectiveness of the end coating.

Initial Temperature

Initial temperatures of 125° or 130° F. are believed to be safe. Initial temperatures above 120° F., however, have been used only to a very limited extent and cannot be recommended with assurance until experience indicates further that their use is desirable. Furthermore, in drying material green from the saw, such low initial temperatures are not particularly detrimental to total drying time as increases in temperatures, especially towards the end of the run, can be made as the drying progresses.

Relative Humidity

Initial relative humidity is not particularly critical. Early experiments designed to establish the minimum initial relative humidity that could be used without producing surface checking failed because no checking occurred even in initial relative humidities as low as 67 percent. Apparently, an initial relative humidity of 75 to 78 percent is entirely safe, and is, moreover, conducive to rapid drying. Initial humidities as low as 70 percent are believed to be safe, but it is conservative to keep above 70 percent because of the variations of drying conditions that are more or less common in any kiln.

In several experimental kiln runs the relative humidity was lowered from the initial condition to 25 percent during the first 6 to 9 days without producing surface checks or any apparent end checks. This result further indicated the ability of black walnut to withstand relatively severe humidity conditions provided it has adequate end protection. Both experimental and commercial data indicate that the initial relative humidity can be gradually lowered to 30 or 25 percent during the first 12 or 14 days of drying. Lowering the relative humidity by reducing the wet-bulb temperature on a time basis aids rapid drying without subjecting the material to conditions that produce drying degrade. Under this method, most or all of the relative humidity changes are made before the temperature is increased.

Intermediate Temperatures

Intermediate temperature changes should be based on the moisture content of the wood. The use of high temperatures while the wood is above the fiber-saturation point (approximately 30 percent moisture content) is apt to result in serious degrade.

This danger was made apparent by excessive degrade that resulted when a commercial kiln load of green blanks was dried by a schedule wherein the desired decreases in relative humidity were obtained by maintaining a constant wet-bulb temperature and raising the dry-bulb temperature from 130° to 165° F. before all the wetter stocks had dried to the fiber-saturation point. Fast drying without degrade was obtained in a similar experimental schedule employing even higher initial and final temperatures. The method is dangerous, however, and may cause excessive degrade when used for commercial drying because of the greater variability of drying characteristics encountered in wood obtained from various localities having a wide range of growth conditions.

A temperature much above 130° F. is not recommended before the wood has dried below the fiber-saturation point. The first temperature changes should be conservative, allowing for any slow-drying or particularly wet blanks that are not as dry as the kiln samples indicate. After the blanks have dried further, the temperature can be increased more rapidly. At the time of intermediate dry-bulb temperature changes, the wet-bulb temperature should also be changed to maintain the desired equilibrium moisture content (the moisture content that wood will eventually attain at any given condition of temperature and relative humidity).

Final Temperatures and Relative Humidities

The final temperatures and relative humidities to be used in the kiln drying of black walnut gunstock blanks are governed largely by the effect of high temperatures on the strength of the wood and the effect of low final relative humidities on the final moisture content. The Laboratory considers

165° F. to be the maximum temperature desirable from a strength standpoint, and higher temperatures are not recommended, even though they do increase the drying rate and tend to reduce the occurrence of wet cores. The use of 165° F. after the blanks have been dried to an average cross-sectional moisture content of 15 percent is believed safe. A final relative humidity of 25 or 30 percent (equivalent to an equilibrium moisture content of 3.5 or 4.0 percent) is considered desirable. Higher humidities will retard the final drying period, and lower relative humidities will produce excessive shrinkage and dryness.

Final Conditioning

A final conditioning treatment is necessary to relieve casehardening stresses that develop during the usual kiln drying procedure. Final conditioning distributes moisture more nearly uniformly within the wood. Combinations of temperature, relative humidity, and time were tried experimentally to determine the best conditioning treatment for 2-1/2-inch blanks. The experiments indicated that drying stresses can be satisfactorily relieved at a relative humidity of 65 percent and a temperature of 165° F. for 24 hours. They further showed that a final conditioning treatment at a given temperature and relative humidity will relieve the drying stresses only of blanks that are within a limited range of moisture content.

As an example, the recommended conditioning temperature of 165° F. and relative humidity of 65 percent (equivalent to an equilibrium moisture content of about 8.5 percent) will not produce the desired stress relief in blanks having a moisture content higher than approximately 8 percent, and will cause reverse casehardening in blanks having a very low moisture content.

The best relief of drying stress will be obtained if the blanks have been dried to a uniform moisture content throughout the kiln load. The degree of uniformity of moisture content increases as the blanks continue to dry. A kiln load dried below 8 percent moisture content will be more nearly uniformly conditioned than a similar kiln load having a higher moisture content. A uniform moisture content of 6 to 7 percent in the dried blanks is desirable to prevent shrinking and end checking in cores exposed by end trimming to the dry air of heated shops during the winter months. Tests show that blanks having a core moisture content above 10 percent are apt to check in the core area when exposed to dry shop conditions after being trimmed to length.

Storage of the kiln-dried blanks before manufacture into gunstocks also helps to equalize residual drying stresses and moisture variations.

Recommendations and Precautions

For the most effective protection against end checking, green blanks should be end coated immediately after sawing. An end coating should be used that will adhere to green end grain and will form a continuous moisture barrier capable of withstanding the abuse of repeated handling of the blanks. The end coating should be able to withstand the temperatures encountered in the kiln during drying.

Recommendations regarding a schedule for drying black walnut gunstock blanks are subject to modifications in order to obtain the best drying in the many different types and kinds of lumber dry kilns. The schedule in table 1 is designed for a modern forced-circulation compartment kiln with automatic control of temperature and relative humidity.

Table 1.--Proposed commercial kiln schedule for drying black walnut gunstock blanks

Temperature schedule		
Moisture content at which change is to be made	:	Dry-bulb temperature
<u>Percent</u>	:	<u>°F.</u>
Above 35.....	:	120
At 35.....	:	125
At 30.....	:	130
At 25.....	:	140
At 20.....	:	150
At 15 and to final.....	:	165
Relative humidity schedule		
Duration of drying	:	Relative humidity
<u>Days</u>	:	<u>Percent</u>
1st and 2nd.....	:	77
3rd and 4th.....	:	74
5th and 6th	:	70
7th and 8th	:	65
9th	:	60
10th.....	:	50
11th	:	40
12th to final.....	:	30 or less

In general, slightly lower initial relative humidities can be used in natural-circulation kilns. Lower initial relative humidities are desirable to prevent mold in the slow drying areas of natural-circulation kilns. Because of the slower drying rate, however, the drying time for each relative humidity step should be extended, possibly an additional day.

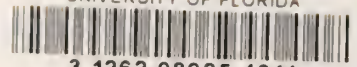
In using this schedule the temperature is governed by the moisture content of the kiln samples. The relative humidities to be used with these temperatures are shown on a time basis. Thus, blanks in the kiln for six days may have dried from 70 to 50 percent moisture content and the temperature should then be maintained at 120°F. until the blanks have dried to a moisture content of 35 percent. The relative humidity, however, will have been lowered on the time basis from 77 to 65 percent after 6 days of drying.

This schedule is considered safe for drying sound, well end-coated and preferably unstained black walnut gunstock blanks. More severe drying conditions should not be used unless experience indicates the practicability of such a change.

Higher temperatures increase the danger of degrade, especially when applied before the average cross-sectional moisture content has reached the fiber saturation point. Even after the moisture content of the samples indicates a moisture content below 30 percent, only moderate temperature changes are recommended because of occasional high moisture content cores or wet spots. As the core fibers begin to dry and, in drying, become stronger, the higher temperatures can be used with greater safety.

In general, final conditioning to eliminate casehardening should be carried on for 24 hours at a temperature equal to the final dry-bulb temperature and at a relative humidity equivalent to an equilibrium moisture content 2 percent higher than the average cross-sectional moisture content of the material. For example, if the final temperature is 165°F. and the blanks have dried to a moisture content of 6 to 7 percent, they should be conditioned for 24 hours at a temperature of 165°F. and a relative humidity of 65 percent. The more nearly uniform the moisture content among individual blanks, the more nearly uniform will be the relief of the casehardening stresses.

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